RESILIENCE TO FLOODING – DRAFT BUILDING CODE

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Exeter, United Kingdom
Why are we discussing resilience?

What is resilience?
What is behaviour of a Flood Defense Systems (FDS) beyond their designed capacity by a flood?

Will the barrier fail catastrophically, with loss of life?
For Hurricane Katrina, a lack of resilience in the system was a major factor in the flooding and losses.
Lack of Resilience
Numerous I-walls failed due to overtopping and erosion

Katrina caused 50 major breaches in the hurricane protection system; 46 were due to overtopping and erosion. Four breaches occurred before water levels reached the top of the floodwalls and have been attributed to foundation failure.
System was not a System
Incomplete; transitions
Without resilient features when/if a FDS is overtopped, the protected community maybe at much greater risk than if the protection had not been built, as the potential energy stored behind the wall is suddenly released.
There is growing recognition (but little guidance) on the need for resilient systems.
WHAT IS RESILIENCE?
Resilience is the ability of a system or a component of a system to sustain loads greater than the design load allowing the system or component to fail gradually, over some duration of time, rather than suddenly and without warning.
Flood Hazard Curve
Rare/High Consequence Events

- Median Flood Frequency
- Wall at 150 Yr
- Wall at 500 Yr

Frequency in Years
Elevation Feet NGVD 1929
A town where 25,000 people reside or work is located in the flood plain of a river.
The river frequently exceeds flood stage.

The hydrology of the basin is such that there is sufficient time to warn and evacuate residents when flooding occurs.

Flooding in the area has resulted in large economic losses for the community.
A floodwall is constructed to protect the community.
The floodwall is designed to withstand the 150 year flood event. The floodwall protects the community from economic losses.
For low level systems it is only a matter of time before a flood defense structure is overtopped.
The 500 year flood event arrives for our project **without resilient** features…

The floodwall is overtopped and fails catastrophically.

There is no warning and **little time** to evacuate the residents.

Loss of life!
Or they could have built same 150 year floodwall with Resilient Features.
The 500 year flood event arrives…
• The floodwall performs as designed, no catastrophic failure.
• There is **time** to evacuate the residents and no lives are lost.
• Although for the overload event, economic losses will be significant, these resilient features will allow for the community to survive with less recover time.
• **Scour and Erosion:**

• **Failure Mechanisms:**
  – Overtopping from surge and waves
  – Erosion of the protective side levee embankment adjacent to the wall

• **Lessons Learned:**
  – Provide an erosion-resistant surface on the levee adjacent to the wall on the protective side

Scour hole formation by overtopping jet (from Hoffmans and Verheij 1997)
Note resilient features, controlled overtopping section with armouring.
Resilient structures should not fail catastrophically when actual loadings exceed the design load.
Scour protection shall be provided at all wall to embankment transitions.
Many believe there is a correlation between recent catastrophes, failures in FDS, and Global Warming.

What is accuracy of water level predictions?

What was believed to be a once in 100 year flood may occur more frequently.

"Across Europe, the greatest natural threat in the coming years will be flooding as global warming sends more water gushing through passageways bordered by densely populated areas and overdevelopment, according to many water and engineering experts. The potential for catastrophic devastation and death is so high in so many countries that the European Union is preparing continent-wide guidelines for water management and flood control.” (Molly Moore, The Washington Post Foreign Service).
• With resilient features, a FDS can survive an overtopping flood event with no catastrophic failure.

• There is time to evacuate with minimal or no lives are lost.

• Flooding occurs gradually instead of in a sudden surge
Resilience is characterized by:
1) failure:
   • sudden → gradual
2) performance:
   • disposable → sustainable
Sustainable Asset

• Without resilient features, a FDS will probably have to be replaced or significantly repaired when first overloaded.
• Any FDS that is disposable after one overload, with a sudden failure mode and loss of life, is unacceptable.
• If engineered systems are not safe and resilient, then they will be essentially disposable features and not sustainable assets.
• While it is recognized that an **Integrated Water Basin** perspective would include retention zones, restricted developments in flood plains, land use planning, awareness raising, flood resistant construction, drainage and water storage improvement, compartmentalization, effective evacuation planning and other measures.

• It is emphasized that **embankments (the hardware parts)** are only one part of a fully functioning Flood Defence System.
While **failure** scenarios to overloading can manifest themselves in many components of a FDS, a **key** resilient feature for many systems is to provide an overtopping section with armouring.
What to do with deficient, Non-Resilient Structures? Do you live within a FDS, is it resilient?

• Societal demands on funding will make it difficult to repair all deficiencies

• Need to have effective prioritization programs that weigh cost against consequences to achieve tolerable risk levels.

• Minimal re-investment may significantly reduce loss of life
Approach Design with Humility

• Of all the “lessons learnt”, the most important is to explicitly incorporate the consequences of failure and the possibility of being wrong in one's assumptions into the design process.

• Building in the flood plain will always have risk; the public should not develop a false sense of security just because a FDS is place.
What is behaviour of a Flood Defence Systems (FDS) for floods above design?

Will the barrier fail catastrophically, with loss of life?

Need a Flood Resilience Building Code to provide resilience to flooding.
• Need comprehensive “lessons learnt” for the system (all components) to ensure resilience.

• For new construction and rehabilitation of existing structures.
Goal is to identify methods for ensuring resilience to the system by requiring it to survive overloads without catastrophic failure, endure only cosmetic damage, be capable of withstanding the design loads after the flood event passes and returning to normal service.
Recommendation is to further develop this relevant information into a comprehensive Model Flood Design Building Code.
• Does relevant guidance already exist?
• Please contact authors if interested in developing a Resilient Flood Defence Building Code.

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Questions
17th Street Canal breach
Inner Harbor Navigation Canal breach
Inner Harbor Navigation Canal breach
Flooding in Lower 9th Ward, St. Bernard Parish
Flooding in Orleans Parish